A multivariate analysis of habitat determinants for *Triturus vulgaris* and *Triturus carnifex* in north western Italy

Ivana PAVIGNANO

Dipartimento di Biologia Animale,
Via Accademia Albertina 17,
10123 Torino, Italy

The distributions of *Triturus vulgaris* and *Triturus carnifex* were studied at 80 ponds in north western Italy, in relation to a number of specific habitat features.

To establish what ecological characters can discriminate between used and unused breeding sites, several environmental factors were measured at each of these ponds and analyzed by multivariate methods. Discriminant variables for both species are : open water surface, percent vegetation around the pond, terrestrial habitat occurring near the pond, age of the pond and human interference. For *T. carnifex* both pond depth and surface also emerged as discriminant factors.

Differences between breeding site characteristics for the two species can be summarized as follows : *T. carnifex* prefers larger and deeper ponds.

T. carnifex is present with *T. vulgaris* only in deep ponds, larger and with more open water surface.

INTRODUCTION

With respect to habitat preferences, *Triturus vulgaris* and *Triturus carnifex* are among the most selective Amphibian species found in Piedmont (north western Italy) (PAVIGNANO & GIACOMA, 1986).

T. carnifex, formerly considered an Italian endemic subspecies of *T. cristatus*, actually represents a separate species, like all other "subspecies" of the crested newt (BUCCI-INNOCENTI et al., 1983).

Even though habitat features may well influence the distribution of newt species, only a few studies on the characteristics of breeding sites are available. These studies, however, did not make it possible to predict which environmental features may be responsible for the choice of breeding sites, at least in a general and comparable way (GIACOMA, 1985).

What is known, is that *Triturus vulgaris* is present in a wide range of pond habitats, while *T. cristatus* is more specialized, preferring larger and deeper ponds (HAGSTRÖM, 1979; DOLMEN, 1983a). DOLMEN (1983a) assumes that the warty newt requires the open water with a minimum of 1 m depth.

BELL (1970) and BEEBEE (1973) consider small pools to be typical smooth newt breeding sites in respect to warty.

Both smooth and warty newts tend to be associated with well-weeded sites, which give spawning places as well as food and cover from predators. However, they can also be found in ponds without vegetation (FUHN & FREYTAG, 1961 ; DOLMEN, 1983a).

T. cristatus is only occasionally found in the absence of *T. vulgaris* (BELL, 1979 ; PRESTT et al., 1974). Where they coexist in the same pond, *T. vulgaris* is nearly always more abundant than *T. cristatus* (BELL, 1979 ; GLANDT, 1978, 1982). Warty newts prefer ponds with a high proportion of open water surface (COOKE & FRAZER, 1976).

Concerning water quality, *T. cristatus* is apparently far less tolerant of acidic waters than *T. vulgaris*, and rarely breeds in more acidic than neutral conditions (CREED, 1964 ; HAGSTRÖM, 1979), even if FUHN & FREYTAG (1961), OKLAND (1979) and HAGSTRÖM (1979) found *T. cristatus* breeding in acid waters. The smooth newt can be present in metal-rich waters, particularly in those with a high calcium content. Both species, however, are common in hard waters (COOKE & FRAZER, 1976).

The two species therefore show a wide ecological amplitude with respect to water qualities and pond types.

In this study I have carried out multivariate analysis to identify which habitat features are characteristic for *T. vulgaris* and *T. carnifex* (ecological variables for *T. carnifex* have been compared with *T. cristatus* ones, because *T. carnifex* is the nearest species to *T. cristatus* as regards systematic data) and also to point out which ecological factors make it possible to differentiate used and unused breeding sites into separate groups.

I have also tried to quantify ecological variables by using statistical data that can be generalized and compared with those from different geographic areas.

Multivariate analysis has long been used for ecological studies in general (ALATALO & ALATALO, 1977 ; ORLOCI, 1966), and, i.e., for bird communities (RICE et al., 1983 ; WILLIAMS, 1978). BEEBEE (1983) used discriminant analysis to identify the most important ecological features for five amphibian species. PAVIGNANO et al. (1989) described the use of several methods of multivariate analysis applied to amphibian communities.

MATERIALS AND METHODS

During the early spring of four consecutive years (amphibian breeding seasons from 1985 through 1988), 80 ponds were sampled at three separate areas in north western Italy (Piedmont).

All sites are temporary ponds, either located in fields or in deciduous mesophilous woodlands. Most of them are artificial ponds.

Field methods employed to identify the use of ponds by amphibian species, or to measure various habitat parameters, have already been described in a previous work (PAVIGNANO & GIACOMA, 1986). Ponds were classified by the following parameters : (1) surface area, (2) depth, (3) extent of aquatic vegetation cover, (4) percent of vegetation around the pond (vegetation covering the ground around the pond), (5) age of the pond, (6) pH, (7) water hardness, (8) NO_2^-, (9) NO_3^-, (10) NH_4^+, (11) H_2S, (12) PO_4^{--} (continuous variables), (13) type of terrestrial habitat occurring near the pond (deciduous woodland, arable, meadow, scrub) and (14) level of human interference (discreet variables).

Level of human interference was estimated by observing the various kinds of human activity, and giving to each of them a score : 0 = no activity ; 1 = water used for home purposes ; 2 = water used for field irrigation ; 3 – periodic mowing of edges by farmers ; 4 = cleaning of edges and shaping of bottom ; 5 = full artificial dry-up.

Chemical water parameters were measured by (FARMATRON) volumetric kits on field ; pH was measured with a portable HANNA HI 8424 pH Meter, fitted with an automatic temperature compensator. Kits sensitivity was : water hardness 0 – 6°F, NO_3^- 0 – 10 mg/l, NO_2^- 0 – 0.05 mg/l, NH_4^+ 0 – 0.05 mg/l, H_2S 0 – 0.5 mg/l, PO_4^{---} 0 – 0.01 mg/l.

Discriminant analysis is a multivariate technique capable of classifying and predicting : it allows to distinguish between the groups so that future subjects may be correctly grouped. Discriminant analysis, together with multivariate variance analysis and cluster analysis, is therefore a method based on the differences among groups of objects. Only discriminant analysis, however, gives either the classification or the predictivity of the classification itself.

Discriminant analysis was carried out using SYSTAT Package.

RESULTS

In the studied area, *T. vulgaris* inhabits 56 ponds (70 % of the total) ; in 35 of these (44 % of the total), *T. carnifex* was also found. The latter species, therefore, was never encountered alone.

Used and unused breeding sites for each of the two species were studied by discriminant analysis (fig. 1 ; Tables I and II).

Figure 1 demonstrates how the discriminant function separates habitats according to the presence or the absence of newt populations.

Group centroids are the average discriminant scores for each group. Transformation of WILKS' lambdas into χ^2 values (Table I) shows that all the discriminant functions obtained are statistically highly significant.

In Table II it is shown by the criterion of classification accuracy, that success ranged from 94 % of sites being correctly allocated in the case of *T. vulgaris*, to 92 % for *T. carnifex*. Three ponds apparently suitable for *T. vulgaris*, and three for *T. carnifex* were inhabited by no newt. Five ponds apparently suitable for both species were inhabited only by *T. vulgaris*. This may depend in the first case on the occurrence of geographical barriers (i.e. a large street, a hill). In the second case, the absence in two sites of *T. carnifex* may be explained by the relatively small pond area being at least 1 meter deep. 5 % of unsuitable ponds were inhabited by *T. vulgaris*, 8 % by *T. carnifex*, 14 % by both species.

Significant variables for both species are : open water surface, percentage of vegetation around the pond, age of the pond, terrestrial habitat occurring near the pond, and level of human interference. For *Triturus carnifex* only, depth and surface of the pond also proved significant.

Water chemical characteristics proved to be non-significant (values of these variables do not significantly differ among the various ponds) (Table III).

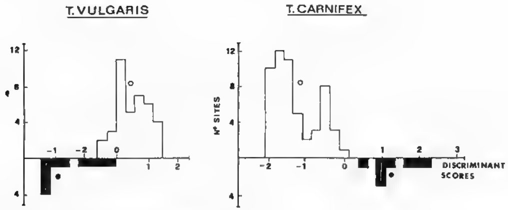

Fig. 1. – Discriminant grouping patterns.

Sites are grouped at interval widths of .2 units.

Sites without species are grouped above the discriminant score line and those with the species are below.

○ and ● represent group centroids.

In order to discriminate between ponds used by *T. vulgaris* only, or by *T. vulgaris* and *T. carnifex* together, another discriminant analysis was carried out only on used ponds (fig. 2, Tables I and II).

In this case the difference between groups also proved highly significant.

The most important variables are : surface area, depth and open water surface. *T. carnifex* is present with *T. vulgaris* only in deeper and larger ponds, having less aquatic vegetation.

The distribution of both species in relation to the habitat characteristics of breeding sites is shown in Table IV.

T. carnifex was found in 35 out of 50 large sites (area of 100-1000 m^2 and > 1000 m^2), in 35 out of 55 deep ponds (depth of 50-100 cm and > 100 cm) and in 20 out of 28 sites with little aquatic vegetation (< 20 %).

Table I. – Significance of discriminant analysis.

Species	Canonical correlation	λ Wilks	χ^2	Significance
T. vulgaris	0.652	0.574	30 506	0.000
T. carnifex	0.639	0.592	28.835	0.000
T. vulgaris and *T. carnifex*	0.825	0.319	30.847	0.000

Table II. – Success rates of discriminant classification.

Site numbers observed refer to those known to be used (+) or unused (−) by the two species. Predicted numbers are shown as those expected to be used or unused on the basis of discriminant function.

% correct refers to site numbers observed/site numbers predicted.

Species	Site numbers observed		Site numbers predicted		% correct
	+	−	+		
T. vulgaris	56	24	59	21	94
T. carnifex	35	45	38	42	92
T. vulgaris and *T. carnifex*	35	45	40	40	87

Table III. – Chemical water factors.

Variables (n sites = 80)	M	Min	Max	SD
pH	7.1	6.5	7 5	0.30
Water hardness (°F)	12.5	12.0	14.0	0.01
NO_2 (mg/l)	0.05	0.00	0 06	0.14
NO_3^- (mg/l)	0.02	0.00	0.01	0.01
NH_4^+ (mg/l)	0.02	0.00	0.02	0.01
H_2S (mg/l)	0.05	0.01	0 13	0.02
PO_4^{--} (mg/l)	0.01	0.00	0.02	0.01

Table IV. – Characteristics of breeding sites and presence of newts.

Variables	All sites	Sites with only *T. vulgaris*	Sites with *T. vulgaris* and *T. carnifex*
Surface (m^2)			
< 50	17	11	–
50-100	13	10	–
100-1000	25	17	17
> 1000	25	18	18
Depth (cm)			
< 50	25	21	–
50-100	29	20	20
> 100	26	15	15
% extent of aquatic vegetation cover			
< 20	28	21	20
20-50	20	13	13
> 50	32	22	2
Total numbers of sites	80	56	35

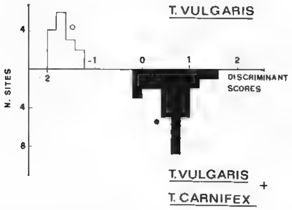

Fig. 2. – Discriminant grouping patterns. Sites with *T. vulgaris* and sites with both *T. vulgaris* and *T. carnifex*.

T. vulgaris seems to be indifferent either to the extent or the depth of the ponds, requiring in any case a great quantity of aquatic vegetation. Deciduous woodlands and scrubby terrestrial habitat structure are optimal for both species.

The breeding sites preferred by the two species are ponds with heterogeneous vegetation and with low level of human interference.

Discussion

The use of discriminant analysis made it possible to distinguish between habitats used and not used by the two species of *Triturus* as breeding sites. The most important habitat characters for both species are : extent of aquatic vegetation cover, vegetation around the pond, terrestrial habitat, human interference and age of pond.

For *T. carnifex* only, pond depth and surface are also discriminant.

The chemical parameters of studied ponds, in opposition to northern Europe (Cooke & Frazer, 1976), do not vary so much to influence the distribution of newts.

In northern Europe *T. cristatus* seems to prefer bog localities or farming/clay areas and to be nearly absent from lakelets, forest ponds, rock-pools and reed-bed tarns while *T. vulgaris* occupies a wide range of locality types (Dolmen, 1980). In northern Italy both species avoid the ponds in fields, because of the strong human interference.

According to Cooke & Frazer (1976) and Dolmen (1983a) differences between breeding sites of the two species would be the following: both species tend to colonize the well-weeded sites, which give spawning places, food and cover from predators ; but *T. cristatus* prefers large, deep ponds, with more open water surface.

T. vulgaris breeds in a wider range of habitats ; for this reason it may be considered a "more eurycious" (that is, it shows a wider ecological amplitude as regards pond types) species than *T. carnifex*.

Many ponds are apparently suitable for both species and coexistence is frequently observed, but only in deeper and larger ponds.

DOLMEN (1980, 1983b), GRIFFITHS (1987), GRIFFITHS & MYLOTTE (1987), HAGSTRÖM (1979) and STRIJBOSCH (1979, 1980) observed in syntopic populations a microhabitat partitioning : *T. cristatus* occupies the centre of the pond, where it is deeper and there is more open water surface.

Various studies have shown habitat features for these two species, but the results are often difficult to compare because of considerable differences in the methodological approach. These results are often very complex and different ; the use of statistical analysis could give values in a general and comparable way.

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